NETL's Office of Fossil Energy

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Roadmap Update for Natural Gas Infrastructure Reliability

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TABLE OF CONTENTS

1.0 SECURITY AND ENERGY ASSURANCE 1

2.0 R&D GROUP 6

3.0 INTERDEPENDENCIES, MODELING AND INTEGRATION.......................14

SECTION **1.0**

SECURITY AND ENERGY ASSURANCE

Participants:
Security and Energy Assurance

NAME	ORGANIZATION

FACILITATOR:

Security and Energy Assurance

TABLE 1-1. BARRIERS

◆ = TOP PRIORITY

PHYSICAL PLANT: MONITORING & LIMITATIONS	DETECTION: UNDERGROUND FACILITIES & LEAKS	OUTSIDE FORCE DAMAGE (INCLUDING THIRD-PARTY)	DATA ACQUISITION & INFORMATION TECHNOLOGY	SYSTEM MONITORING, ANALYSIS & CONTROL	REGULATORY & INSTITUTIONAL	CONSTRUCTION, MAINTENANCE & REPAIR	SECURING THE INFRASTRUCTURE	
• Material limits on T&D • Monitoring of physical plant condition • Inadequate tools to evaluate pipeline integrity ◆◆ • Lack of predictive pipe–failure models • Need better pipeline inspection tools–internal and external ◆◆◆◆ • Get back to operating at design capacity ◆	• Lack of technician to locate and identify facilities • Rapid leak detection needed–remove, non-intrusive • Ability to locate non-metallic pipe	• Warning of third-party intrusion ◆◆◆◆◆◆ ◆◆◆◆ • Real-time damage detection ◆◆◆	• Converting data, real-time tools • Lack of sensors for dynamic applications • Lack of automated information/data management • Ability to handle complex information during emergency	• Lack of understanding of transient flow and impacts • Lack of real-time consumption information • Systems to respond to, variable delivery cycles • Improving overall efficiency of pipeline and compressors ◆◆◆	• Limitations on operating pressures • Common basis for technical evaluation and certification • Permitting process • Limited dollars for technical improvement ◆◆ • Environmental concerns ◆◆	• Better guided boring technologies • Ability to excavate quickly without damage to underground utilities ◆◆◆◆ • Need low-cost pipeline rehab/retrofit technology ◆ • Lack of intelligent, trenchless technology	• Threat and vulnerability assessments needed ◆◆◆◆◆ • Security/ classification of information ◆ • Lack of industry standards for secure information and protocol communication ◆◆◆◆◆◆ • No hardened secure communication technologies ◆◆◆◆ • New level of complexity, information sharing and control • New organizational ties need to be established • Large, diffuse infrastructure: remote ◆◆◆◆ • Accessibility of facilities (compressor stations, need quick response ◆◆◆ • Exposure of above ground pipes ◆◆◆◆ • Moving gas to areas of greatest need after emergency • Identify responsibilities and liability of problems ◆◆	• New funding question: Who pays? ◆◆ • Response to security needs with financial and manpower constraints ◆◆◆ • Different assurance objectives at work • Need for fuel flexibility at end-use for more robust system ◆ • Operational efficiencies among infrastructure (H_2O, electric, etc.) • Balancing need to investigate versus getting back on line • Educating the public ◆◆◆ – instructions – emergency resource – damage control • Need an active system to respond/prevent ◆◆ • Emergency responder training and protocol • Controlling internal threats (within companies) • Voluntary versus required mutual assistance

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Table 1-2. Opportunities
◆ = Top Priority

Third Party Damage	Compressors	Materials	Education & Training	Funding Issues	Pipeline Efficiency
• Right-of-way monitoring ◆◆◆◆◆◆◆◆◆◆ – Satellite imaging ◆ – Real-time detection • Warning 3rd party intrusion equipment and software needed, user-friendly GPS • Soft dig excavator ◆◆◆ • Minimize 3rd party damage with improved GPS data • Rehab technology to reduce likelihood of failure from 3rd party damage ◆◆	• Retrofit technology to widen operational range of computer equipment • Retrofit technology to reduce fuel cost ◆ • Retrofit technology to uprate existing horsepower ◆ • Retrofit technology to meet more stringent environmental requirements ◆◆	• Plastics technology, self-healing ◆ • Retrofit ballistic armor pipe covering for above-ground piping protection ◆	• Internet-based network for online training • Educational tools, methods and training for dissemination to the public	• Joint industry-regulatory work group to explore funding issues ◆ • Funding—possible clearing house of any government funds available	• Cost-effective methods ??? ??? efficiency
Security	**Underground Detection**	**Boring**	**Inspection**	**Automation**	**Repair**
• Infrastructure location classification system ◆◆◆ • Pipeline "force-field" with tie-ins for crews ◆◆◆ • Perimeter (fence), motion detection (economic) ◆◆◆ • Develop low-cost application other end-use controls that operate under broader range of gas supply characteristics • Conduct vulnerability assessment for N.G. system ◆◆◆◆ – Educate the industry on VA results • Autonomous isolated facility stand-alone security system ◆◆ • National Emergency Warning System ◆◆◆◆◆◆◆ • Sharing of imagery, DOD satellites • Standard communication method that flows from governmental agencies to field ◆◆◆◆◆ • Secure SCADA systems – Standards for secure communication – Hardware and software encryption (transfer) • test facility to confirm (Ross mfgr comm. capability	• Acoustic device for leak detection and 3rd party hits ◆◆◆	• Boring equipment with real-time damage detection ◆◆◆◆	• Inspection tools for ?????? mains ◆◆◆◆◆ – Self-propelled internal inspection tool	• Develop industry standards (non-proprietary) for controls and communication equipment ◆◆◆	• Develop construction excavation equipment for low cost street trenching, moves fast, minimizes mess ◆ • Rapid micro/keyhole excavation tools for external corrosion DA validation

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TABLE 1-3. IMPLEMENTATION PLANS

	CHARACTERISTICS & REQUIREMENTS	R&D ELEMENTS	CRITICAL STEPS	COLLABORATIONS	SCHEDULE & MONEY
RIGHT-OF WAY MONITORING/THIRD PARTY DAMAGE PREVENTION	• Third-party damage control mechanisms • Accurate GIS map with automatic (instant) update • Reliable, no false positives • Devices that alert people from unintentional intrusion • Real-time information • Discern normal activity versus abnormal activity • One-call system with monitoring activation	• Early warning of intrusion to company/"outsider" • Communication mechanisms, secure • Intrusion prevention devices ("turn off a backhoe), device that feeds to GPS • Use fiber optics to integrate with detection system – Sensing devices that discriminate – acoustic – satellite imaging – invisible • "Fields" around buried pipes, radio signals around metal pipe – retrofit for existing pipe – new construction – tracer wires for plastic pipes	• Sound GPS/GIS system • Sound business case • Integrate with partners; spread risk/cost/ responsibility – ideal but hard to obtain • Easy, quick and cheap to implement (sensors, comm, er), use existing facilities	• Common ground alliance • Pipeline companies • LOCs • Regulators • OEM/manufacturer/ suppliers • One call organization • Researchers • Federal government research money • Satellites	• For/use alliances with other infrastructure • Identify most critical element – common ground alliance • Five- to ten-year time frame
SECURE SCADA SYSTEMS	• Impervious to outside attack, no hackers • Perform current functions with no degradation • Applicable to existing hardware • Self-checking system, smart	• Agree upon industry consensus standard • Easily, automatic, low-cost updating of software • Testing and certification facility for ensuring interoperability of manufacturing equipment • Encryption algorithms and software development • Expert analysis of secure system • More sophisticated cyber monitoring and screening – wireless systems are not secure – hacker test facility	• Security vulnerability assessment • Agree on common standard • Examine how to leverage off of existing technologies • Resolving national and private interests	• SCADA and process control equipment vendors • Software engineers, various fields • Security experts (government, contractors, etc.) • Common ground alliance/other infrastructures • National issues—DOE, industry trade organizations • Federal government industry cooperation needed with money	

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TABLE 1-3. IMPLEMENTATION PLANS *(CON'T)*

	CHARACTERISTICS & REQUIREMENTS	R&D ELEMENTS	CRITICAL STEPS	COLLABORATIONS	SCHEDULE & MONEY
GOVERNMENT ROLE	• Government facilitated demonstrations – industry state-of-the-art – crossover and ??? from other industries • Government test bed facility • Showcase technology • Test new devices • Physical security of critical facilities – compressors – above-ground facilities (valves) – storage – meters – above-line valves				

SECTION 2.0

R&D GROUP

Participants:
R&D Group

NAME	ORGANIZATION
Bob Bass	SWRI
Dan Driscoll	DOE/NETL
Paul Gustilo	AGA
Dave Johnson	Enron
Abraham Knuk	NRCan
Shreekant Malvadkar	DOE/NETL
Graham Midgley	Heath Cons.
Bob Moody	CMS Energy
Randy Moss	So. Cross
Bruce Nestleroth	Battelle
Jerry Paulus	City of MESA Gas
George Ragula	PSE&G
Christina Sames	OPS
Crystal Sharp	DOE/NETL
Wes Soyster	Equitable Gas
Andy Theodos	TCO
Bob Torbin	Foster Miller

FACILITATOR: ALICIA DALTON, ENERGETICS, INCORPORATED

R&D Group

Table 2-1. What Are the Technology Issues and Barriers?

Physical Plant: Monitoring and Limitations	Detection: Underground Facilities and Leaks	System Monitoring, Analysis and Control	Outside Force Damage (including 3rd party)		Regulatory and Institutional	Regulatory and Institutional (Continued)	Construction, Maintenance, and Repair	Security
• Material limits on Transmission and Distribution • Monitoring of physical plant condition • Inadequate tools to evaluate pipeline integrity ◆ – Only 30% of all pipeline are able to be inspected • Need better pipeline inspection tools – internal and external ◆◆◆◆◆ • Lack of predictive pipe-failure models • Need for improved compression technologies ◆◆ • No long-term view from purchasing decision makers ◆ • Integrity assessment of unpiggable transmission mains ◆◆◆◆◆◆ • Current accurate map information ◆◆◆ • Lack of large diameter/high pressure CCTV inspection "Live" ◆ • Lack of non-destructive testing for PE joints • Redefine pigging practice ◆◆	• Lack of technology to locate and identify facilities • Rapid leak detection needed- remote, non-intrusive ◆◆◆◆ • Ability to locate non-metallic pipe ◆◆◆ • Lack of cast iron pipe joint locators ◆	• Lack of understanding of transient flow and impacts • Lack of real time consumption information ◆ • Systems to respond to variable delivery cycles • Need more system optimization R&D ◆	• Warning of 3rd party intrusion ◆◆ – Intentional – Accidental • Real-time damage detection ◆	• Converting data → real-time tools ◆ • Lack of sensors for dynamic applications • Lack of automated information data management • Advanced interpretations of close-interval survey data ◆◆ • Data fusion ◆◆ – Format – Hardware – Software	• Limitations on operating pressures ◆ • Common basis for technology evaluation and certification • Permitting process • Limited dollars for technology improvement ◆ • Clean Air Act impact on HP (new and existing compressor stations) ◆◆ • Technology adoption inhibited by combination of regulatory and technology transfer issues • Localized focus vs. industry focus • Decrease in qualified personnel (technical	• Lack of long term funding/vision/ commitment ◆◆◆ • R&D and new materials should be exempt from regulatory Restrictions • Lack of cooperation, communication and data sharing among pipelines, LDCs, electric, etc. ◆◆ • Personnel change – never work with same people twice • Typically have non-technical people writing technical mandates • Lack of idea forums to fully develop ideas ◆	• Need low-cost pipeline rehab/retrofit technology • Better guided boring technologies • Ability to excavate quickly without damage to underground utilities • Lack of intelligent trenchless technology ◆ • Need for recon/ surveillance technologies◆	• Rapid recovery plans for key facilities◆◆ • Real time detection and assessment of adversarial intruders to gate settings/ meters at first barriers ◆◆◆◆ • Real time detection and assessment of intruders to compressor stations at first barriers ◆◆◆

R&D Group

TABLE 2-2. What Are the R&D OPPORTUNITIES TO MEET THE NEEDS?

◆ = TOP PRIORITY

INSTALLATION	3RD PARTY DAMAGE	REGULATORY AND INSTITUTIONAL	UTILIZATION	INSPECTION	REPAIR	MODELING	SECURITY
• Develop sonic excavation tools using harmonics ◆ • Develop programs to enhance trenchless technologies ◆◆ • Construction methods and technology to minimize installation and/or repair	• Combine satellite right of way surveillance with fiber optic cable vibration ◆◆	• Better communication between industry sectors – joint action –gas, electric, transmission, distribution • Split research from development • Develop a standard for mapping ◆◆ • Utilize military technology (military contractors) for industrial/public benefit ◆ • Combine government and industrial R&D efforts/ management ◆◆◆◆ – Allow industry development of ideas and feedback during R&D activities (better communica-tions)	• Natural gas reformer development to reduce air pollution and efficiency ◆ • Add molecule to natural gas to make inert then remove to make flammable ◆ • Commercial, residential storage systems ◆◆	• Develop magnetic flux leverage (MFL) tools for better pit geometry ◆◆◆ • Smaller robotic distribution technologies move through pipelines report anomalies ◆◆ • Through transmission inspection: transmitter inside sensor outside ◆◆ • Sensors for inspection crawlers ◆◆ • Advanced robotic technology for non-piggable mains (transmission) ◆◆◆◆◆◆◆ • Fast response sensor technology ◆ • Inspection pig detecting changes (dents, corrosion, coating)	• Robotic repair of internal corrosion ◆◆◆◆◆	• Develop advanced algorithms to maximize information from existing inspection data ◆ • Infrastructure optimization to improve reliability. Examine all pipelines. Connect logical pipelines via headers – North to South – East and West ◆	• Develop suite of cost-effective surveillance techniques ◆◆◆◆ – Develop satellite images for continuous patrol/survey • Develop standards for security assessments and methods • Put up a force field ◆◆ • Develop DOD-type intelligence to help guide pipelines above ground

TABLE 2-2. WHAT ARE THE R&D OPPORTUNITIES TO MEET THE NEEDS? *(CON'T)*

◆ = TOP PRIORITY

AUTOMATION	MATERIALS	COMPRESSORS	LEAK DETECTION	UNDERGROUND DETECTION
• High speed wireless communication technology ◆ • System optimization – Models – Sensors/controls • Sensor/instrument ◆ – Gas quality – Meters – DE/TVDT – Security – Pipes – Machines	• Coating for PE pipe to reduce installation cost • Non-corroding high pressure piping materials • Materials R&D – New pipes – Making reliability	• Synergies - compression technologies, deliverability, reliability, efficiency, emissions ◆◆ – Existing equipment – New novel techniques – Monitoring controls • New engine technologies countered opposed piston design ◆	• Develop laser technology to leak survey lines above ground ◆◆◆◆ • Visual leak detection using infrared imaging ◆◆◆	• Retrofit device to make PE pipe locatable with current technology ◆◆

R&D Group

TABLE 2-3. PORTFOLIO GAP ANALYSIS

◆ = TOP PRIORITY

PARTIALLY IN THE PORTFOLIO

3RD PARTY DAMAGE	INSTALLATION	SECURITY	LEAK DETECTION	INSPECTION
• Combine satellite right of way surveillance with fiber optic cable vibration ◆◆ – Satellite to assess what's being detected	• Develop programs to enhance trenchless technology ◆◆◆◆ – Elimination of all penetration	• Develop suite of cost effective surveillance techniques ◆◆ – Develop satellite images for continuous patrol/survey	• Develop laser technology to leak survey lines above ground ◆◆◆◆◆◆◆◆ • Visual leak detection using infrared imaging ◆◆	• Develop MFL (magnetic flux leakage) tools for better pit geometry ◆◆◆◆◆ • Smaller robotic technologies move through pipe and report anomalies – distribution ◆ • Sensors for inspection crawlers ◆

NOT IN THE PORTFOLIO

UTILIZATION	COMPRESSORS	REPAIR	UNDERGROUND DETECTION	INSPECTION	REGULATORY AND INSTITUTE	SECURITY
• Commercial and residential storage systems ◆◆◆ – Downstream of meter – Increases service reliability – Peak shaving – Be able to control release (time of day) – time and pressure – Creates additional upstream capacity	• Synergies compressor technologies, deliverability, reliability, efficiency, emissions ◆◆◆◆◆ – Existing equipment – New novel technologies – Monitoring controls – Integrated engine/compressor controls – Use engine waste heat to create new species fuel to intake manifold – reduce emissions, increase efficiency, coil reformer $CH_4 + H_2O \rightarrow CO + 3H_2 +$ (new species – In-line compressors	• Robotic repair of internal corrosion ◆◆◆◆◆ – Robotic repair of external corrosion – Self healing pipe	• (Retrofit) device to make PE pipe locatable with current technology ◆	• Through transmission inspection: ◆◆ – transmitter in pipe – Sensor outside • Advanced robotic technology for non pigable mains (transmission) ◆◆◆◆◆ – Address varied causes of “non-pigable” lines	• Develop a standard for mapping ◆◆ • Combine government and industrial R&D efforts/ management ◆◆◆◆◆	• Put up a force field – Establish 3D perimeter

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Table 2-4. Implementation Strategies

	Requirements	R&D Produces Elements and Specifications	Critical Items and/or Steps (make or break)	Who Leads? Collaborations	Time/$
Develop Laser Technology to Leak Survey Lines Above Ground	• Repeatable, reliable, accurate results • Minimal maintenance requirements • Aerial and hand-held versions • Not more than 2 man operations • Based on other applications if possible • Easy calibration • Methane ethane specific • Has search mode and pinpoint mode • Provide real time data to remote source • Performance equal to/or better than current technology • Increase productivity • Easy, fast setup • Valid in windy conditions • Use by PL operations field staff • Available 24/7 • Equivalent sensitivity to existing equipment • East to use/minimal training	• Eye safe • Lightweight less than 5 pounds • All weather operation $^{-}40^{o}F<T<120^{o}F$ • Range >300' • Multi-sensitive <10 ppm to UEL • Explosion proof intrinsically safe • Weighs not more than 5 pounds • At least 8 hours operation on one charge • Field cal. by non-techs • Non-interfering with other instruments • Use at up to patrol aircraft speeds	• Self calibration • Review existing R&D and either support or drop projects depending on success potential • Keep end-users involved throughout process • Adaptable for hand held and aerial use • Determine minimum power requirements to evaluate safety vs. practicality • Portable and mobile capability	• Leaders – R&D organizations experienced in laser applications – National lab • Collaborators – Industry – Field tests, technical direction, priority/reevaluation – States and DOT needs to be involved and aware	• R&D 2-3 years • $9M

Table 2-4. Implementation Strategies *(con't)*

<table>
<tr><th></th><th>Requirements</th><th>R&D Produces Elements and Specifications</th><th>Critical Items and/or Steps (make or break)</th><th>Who Leads? Collaborations</th><th>Time/$</th></tr>
<tr><td>Combine Government and Industrial R&D Efforts/Management</td><td>• Broad forums and focused groups
• Bring together same people every time
• Frequent meetings several times a year
• Decrease environmental Impacts
• Share in the funding of priority R&D
• Decrease cost
• Review schedule
• Not Ad Hoc
• Maximize benefit of limited resources
• More efficient use of resources
• Co-ordinate defining R&D top needs
• Coordinate in the information distribution and tech transfer</td><td>• Form research advisory group
• Form project advisory group that reports to the research group</td><td>• Inform everyone of work establish a common one page summary for projects</td><td>• Leaders
– OPS, DOE, regions and states, municipals, industry- increase level
• Research advisory (dozen or less)
– AGA, APAGA, NGA, DOT, DOE, NARUC, PRCI
– Individual utilities viewed as R&D industry leaders
– Use organizations to select actual players
– Co-funders to some extent
• Multiple project advisory (segregated by category of research)
– Techies
– Use organizations to select actual players
– Co-funders to some extent</td><td>• ?????</td></tr>
<tr><td>Advanced Robotic Technology for Non Pigable Mains (Transmission)</td><td>• Not interfere with operations
• Maneuver through all obstacles in pipeline
• Easy to launch
• Vehicle capable of multiple sensor technology
• Accurate locating of defects
• Does not miss significant anomalies
• Meet DOT requirements for inspections
• Competitive with other pigging technology
• Repeatable reliable and accurate results
• Detect corrosion and/or evaluate dents and gouges
• Provide digital data
• Can be left in pipeline – long term
• Compatible with current pigging technologies</td><td>• Powered – Bi-directional
• Self powered
• Sensitive to critical defect sizes
• Travel meters to miles
• Use in live gas mains
• Go through as small as 4-inch pipe
• Real time results wireless communication
• Good for up to several miles
• Clear odd-shaped valve openings
• Self-diagnostics</td><td>• Critical step – determine type of sensors
• Operate in fluid filled lines
• Cost-effective
• Vehicle technology
• Regulatory acceptance
• Locate non-piggable lines for "real world" testing
• Is the needed sensor technology available?
• High reliability
• Optical capability
• Start with sensor or vehicle?
• Develop specs for test pipeline
– Valve types
– Slopes
– Moisture
• Self propelled</td><td>• Lead
– LDC's, industry, end-users
• Collaborators
– Vendors
– R&D organizations with robotic and pipe inspection</td><td>• 3-5 years
• $7-10M</td></tr>
</table>

R&D Group

Table 2-4. Implementation Strategies (con't)

	Requirements	R&D Products Element's and Specs	Critical Items and/or Steps (make or break)	Who Leads? Collaborations	Time/$
Synergies – Compressor Technologies, Deliverability, Reliability, Efficiency, Emissions • **Existing equipment** • **New novel tech.** • **Monitoring controls**	• Increase rangeability on existing equipment • Use waste heat to cool intercoolers (absorption) • Provide improvements – Efficiency – Emissions – Reliability – Deliverability • New noel techniques – Inline compression – Variable stake re-cops • Can operate over a wide range of flows • Fit within current physical envelope • High efficiency • Meet anticipated environmental requirements • Integrate engine/compression controls • Can operate over a wide range of pressures	• Smaller and portable • Reduce NO_x etc emissions • No cast metal • Increase valve of blade life • Use less fuel than existing equipment • Use engine waste heat to create new species fuel to intake manifold reduce emissions, increase efficiency – coil reformer $CH_4 + H_2O \rightarrow CO + 3H_2$ (new species) • Handle off-spec gas • Improved security	• Involve control and compressor manufacturers • Acceptance and field testing of novel designs • Market size/costs • Securing initial investment • Generating and approval of new industry standards • Intellectual property (Patent) issues • Determine HP market priority, i.e., size of unit • Target market potential in horsepower	• Lead – End users • Collaborators – Compressor manufacturers – Instrumentation control manufacturers	• 3-10 years • $1-100M

SECTION **3.0**

INTERDEPENDENCIES, MODELING AND INTEGRATION

Participants: Interdependencies Modeling and Integration

NAME	ORGANIZATION
John Bayko	Ontario
Terry Boss	INGAA
Bruce Campbell	GTE
Robert Cupina	FERC
David Damon	Dominion
Gary L. Forman	NISOURCE
Christopher Freitas	DOE/FE
Tom Hancock	TVA
Rondle Harp	DOE/NETL
Walter Kasperczyk	National Fuel Gas
Thomas Kraft	Wisconsin Gas
Shari Dunn-Norman	University of MO
Tony Savino	Keyspan
Nancy Shultz	Williams
Al Yost	

FACILITATOR: KEVIN MOORE, ENERGETICS, INCORPORATED

Interdependencies, Modeling and Integration

TABLE 3-1. WHAT ARE THE TECHNOLOGY ISSUES AND BARRIERS?

◆ = TOP PRIORITY

● PHYSICAL PLANT: MONITORING AND LIMITATIONS	● OUTSIDE FORCE DAMAGE (INCLUDES 3RD PARTY)	● DATA ACQUISITION AND INFORMATION TECHNOLOGY	● REGULATORY AND INSTITUTIONAL	● CONSTRUCTION, MAINTENANCE, AND REPAIR
• Material limits on T&D • Monitoring of physical plant condition • Inadequate tools to evaluate pipeline integrity ◆◆ ✳ Intelligent system needed ◆◆◆◆ ✳ Tools to access operation and maintenance with risk factors ◆ ✳ Real-time vs. discrete continuous measurement ✳ Control system to deliver off-peak • Need better pipeline inspection tools – internal and external • Lack of predictive pipe-failure models	• Warning of 3rd party intrusion ◆◆◆◆◆ • Real-time damage detection ◆◆	• Converting data → real-time tools • Lack of sensors for dynamic applications • Lack of automated information data management	• Limitations on operating pressures • Common basis for tech. evaluation and certification • Permitting process • Limited dollars for tech. improvement ✳ Maintain competition with protection of infrastructure ◆ ✳ Who pays for redundant capacity ✳ Ability to adopt new technology	• Need low-cost pipeline rehab/retrofit technology ◆ • Better guided boring technologies • Ability to excavate quickly without damage to underground utilities • Lack of intelligent trenchless technology ✳ Tools to determine requirements for maintenance and new systems ✳ Repair or replace plastic pipe ◆◆ ✳ Landowner concerns → non-intrusive infrastructure ◆◆◆

✳LONG-TERM STRATEGIES AND CAPABILITIES	✳SECURITY AND VULNERABILITY	✳COLLABORATION INTERNAL AND EXTERNAL	SYSTEM MONITORING, ANALYSIS AND CONTROL	DETECTION: UNDERGROUND FACILITIES AND LEAKS
✳ Loss of long-term focus and capabilities ◆◆ ✳ Need training and dissemination of knowledge ✳ Deregulation and mergers lose capabilities and corporate R&D ◆ ✳ Quarter to quarter vs. long-term strategic approach ◆	✳ Cyber and physical vulnerability ◆◆◆ ✳ Interdependencies: gas and electric systems ◆◆◆◆ ✳ Need cost effective tech for security ◆ ✳ Vulnerability with T&D system interdependencies ✳ Laid off worker sabotage	✳ Develop and better alliances between industry and government ◆◆ ✳ Crossover technologies: pool efforts to get links ✳ Silo effect: compete and compliment ✳ Understand impacts and benefits of tech.	• Lack of understanding of transient flow and impacts • Lack of real time consumption information • Systems to respond to variable delivery cycles ✳ Prediction of failure ◆◆◆◆◆◆ ✳ Flexibility of system tie to economics with models etc. ◆◆◆◆ ✳ Lack of continuity of service after event ◆◆◆ ✳ Affordability of obtaining data	• Lack of technology to locate and identify facilities • Rapid leak detection needed – remote, non-intrusive • Ability to locate non-metallic pipe ✳ Inability to detect small volume leaks

● = Topics identified in earlier roadmapping
✳ = New topics

Interdependencies, Modeling and Integration

TABLE 3-2. WHAT ARE THE R&D OPPORTUNITIES TO MEET THE NEEDS?

◆ = TOP PRIORITY

✳ SECURITY	✳ ALTERNATIVE STORAGE	✳ CONSTRUCTION TECHNIQUES	✳ INTELLIGENT SYSTEMS	✳ ENVIRONMENTAL IMPACTS	● 3^{RD} PARTY DAMAGE
• Develop low cost motion detection, monitoring, sensors/systems ◆◆ • Develop security audit – probe – for company to test their protective systems • (NSF) IGERT analogy • Develop training system for simulated attack – Attack "kit" – "Cascade failures" • Set up a "fly trap" for would be attackers	• Transient surge designs	• Landowner buy in – Co-locate gas, electrical, water in utility carriers – Communicate benefits – Replace existing pipe with higher capacity lines – Improve construction techniques – Low profile/impact ◆ • Trenchless technology to enable installation of 36" pipe like fiber optic duct.	• Take sensing to level of "skin" for intelligent pipelines → models? ◆◆◆◆ • Nationwide energy control systems to be an activated in an emergency – Monitor flows – Route around outage ◆◆◆ • Remote detection systems to passively report flaws, equipment, intruders, etc. ◆◆ • Develop systems for: – Corrosion monitoring – Leak detection – Pressure – Location • Develop long-term sensor/robotic detection and repair for distribution systems continuous • Intelligent system – 3^{rd} party intrusion – Damage detection	• Construction – landowner needs – Compressor noise – Reduction of emissions	• Develop "smart" pipe wireless remote sensing devices for pipelines and excavating equipment ◆◆◆◆ • Detection and prevention of 3^{rd} party damage ◆◆ • Cost effective methods to detect intrusion and provide security in remote locations

● = In existing portfolio
✳ = Not in or partially represented in existing portfolio

Interdependencies, Modeling and Integration

TABLE 3-2. WHAT ARE THE R&D OPPORTUNITIES TO MEET THE NEEDS? *(CON'T)*

◆ = TOP PRIORITY

REPAIR	MATERIALS	COMPRESSORS	LEAK DETECTION	BORING	AUTOMATION	MODELING	
• Lower the cost of the in-the pipe technologies using new designs – Launching equipment – Internal repair methods ◆◆◆◆ • Extending service life of existing infrastructure	• Develop protective/healing materials for exposed pipe • Expandable metals • Material science for HP lines ◆◆◆◆ • Materials – Small diameter – High pressure – Ease of installation – Corrosion resistant ◆	• Flexible compressor design for quick start-up and load following ◆◆ • Second (next) generation compressors 2,500 PSI	• Develop remote methane monitoring and sensing equipment for use in excavations for personal safety ◆	• Obstacle detection for HDD that produces 3-D imaging for all underground structures ◆	• Develop low cost standard comm.. equipment – Plug & play sensors and activators ◆◆◆◆ • Develop redundant and separate controls for lines and communication • Develop handheld devices and software for field data capture to eliminate field paperwork • Develop communication system to share information on status of gas transmission/supply ◆ • Develop national clearing house for system capacity information • Model gas delivery systems and develop "alternate path" strategies (dynamic delivery system) • Improve redundancy in transmission of gas (dynamic modeling)	• Develop information exchange protocols ◆◆◆◆ • Forecasting system of generation and LDC dispatching ◆◆◆◆ • Continuity of service – Post event recovery – Self healing pipe – Redundant pipe – Protocol for supplementing deliveries: – Who's gas? – Who pays? – Who decides? – Standardized categories and alerts/ responses • Define impacts of distributed generation on gas delivery • Forecasting system for gas system based on electric dispatch and LDC ◆	• Modeling to identify worst contingencies (gas) and how it would affect entire energy infrastructure • Failure prediction utilizing non-invasive tools and models • Tools to repair/replace – Decision tree – Cost/benefit ◆ • Real-time flow models that can activate operational adjustments to large swings in load ◆ • Define/model "impact weighted capacity" • Develop better sensor/models to continuously track and predict corrosion • Relation between corporate optimization and global optimization • Provide capture mechanism for pipeline failure data → model if possible? • Risk analysis: Economic vs. actual life cycle

Interdependences
Table 3-3. Implementation Strategies

Topic	Requirements/ Characteristics	R&D Products	Critical Items and/or Steps (make or break)	Who Leads? Collaborations	Schedule and Dollars
Develop Improved Materials for High-Pressure Lines	• 2500 PSI Thinner wall pipelines • Small diameter plastic 100 PSI • Non-corrosive 500-600 PSI for distribution systems – Easy install – Multi-fittings • Retrofit existing systems • Integrate with smart pipe with a brain that talks to you		• Impact on installation, e.g., joints • Cost of pipe equals of cost of materials; thinner matters • There are things-on-the ground now, but cost reality is critical	• Safety and regulatory issues retro and new	
Energy Assurance: Develop Tools to Forecasting/ Integrate Current and New Customer Demand (to guide system development/perf)	• Integrated gas control (across individual companies and systems) • Example requirement: a 1 MW peaker on line in 15 minutes • System inc. storage	• Real-time assessment and modeling	• New load characteristics • Potential for large, rapid swings • Load-change stresses on pipe/equipment	• DOE lead: details to follow • Industry leads operational aspects • NERC	• Note: activities already underway in DOE; do not duplicate
Develop Low-Cost In-the-Pipe Tech. New designs for Launching and Repair	• Smaller excavation • Standard configurations • Top-entry launch • Live gas operations • Flexibility for any tool 6-24” • Applications – Clamp repairs – Joining – Inspection – Cleaning	• Launch system with universal application • Cost-effective and easy to use	• Define market opportunity in gas systems to robotics industry	• Industry university capabilities in “robotics” • Industry crossovers, e.g., nuclear	
Take/Develop Intelligent Systems to Level of “Skin”	• Continuing sensing along system/pipe • Standardization: “Plug & Play” • Data Acq/trans/use – All through system – Multiple end-point – Entirely new sensing targets, e.g., no current/ developing analogues • For application to: – Intrusion Det. – Damage – Degradation – Leak – Failure	• Components – Sensors – Algorithms – Actuators – Feedback system – Data/information protocols	• Nothing without integration • Screen existing/ developmental efforts • Application – specific refinements for these applications • Worry first about – 3rd party: — on equipment — other ways to do it – Failure/leak – Predictive failure	• Intersection with ANSI 12.19 • Intersection with ASTM • State PUCs • FERC	• Near: sensors on equipment and implementation in active projects • Mid: inclusion into planned projects • Long: application on a system-wide basis

Interdependences
Table 3-3. IMPLEMENTATION STRATEGIES *(CON'T)*

TOPIC	REQUIREMENTS/ CHARACTERISTICS	R&D PRODUCTS	CRITICAL ITEMS AND/OR STEPS (MAKE OR BREAK)	WHO LEADS? COLLABORATIONS	SCHEDULE AND DOLLARS
DEVELOP LOW-COST DETECTION (MOTION AND OTHER) AND MONITORING SENSORS/ SYSTEMS	• Key nodes/vulnerability: – Compressors – LNG facilities LPP – High-volume PTS – Pipeline hubs – Interconnects – Low cost <u>means</u> low cost – Nodal assessment – Mobility	• Low-cost tools/methods for zonation/by-pass • Standard product (so many points) to cover; need standard engineering specifications • As costs go down: Satellite-based approaches and others • Blast-resistant materials – but costs?	• Know what is available; what it costs • Tech approach must augment/replace guns/guard and show low cost •	• Industry: – Capability-specific – Driven by states and others – Regulatory push • Coordination: INGAA and other (objective of shared recovery)	• Now if not sooner